[10191/1896]

ROTARY ACTUATOR AND ROTARY SWITCH

[Background Information] Field Of The Invention

The present invention relates to a rotary actuator having a permanently magnetized rotor and a plurality of stator windings surrounding the rotor in a rim-like fashion, for generating

5   magnetic fields that place the rotor in one of a first plurality of positions.

Background Information

Rotary actuators [of this type] can be used as the drive for rotary switches, for example, an

10   "R"-type waveguide switch in satellite technology.

Currently, stepping motors are generally used as actuators for purposes of this type, such as are described in European Patent No. 0 635 929 [B1]. However, stepping motors have a number of characteristics that make them not seem optimally suited as actuators for rotary

15   switches. Stepping motors are generally designed to generate a large torque that is distributed as uniformly as possible in the course of one rotation of the motor shaft, the torque making it possible to smoothly drive a mechanism that is braked using friction. This requires a minute staggering of the stator windings in the circumferential direction around the rotor, necessitating a multiplicity of terminal connections that are cumbersome to connect to wires.

20   Figure 5a depicts an example of a rim-like arrangement of stator windings, which can place an (undepicted) rotor in four positions, each offset by 45° with respect to the others. Stator windings 1 through 4 are divided here into two diametrically opposite segments 1a, 1b,... 4a, 4b. The total of eight segments are mounted on a ring core 5, which lies in the plane of the Figure and perpendicular to rotational axis 6 of an (undepicted) rotor. Figure 5b depicts the

25   alignments of magnetic fields B_1...B_4, which are obtained by sending current through segment pairs 1a, 1b... 4a, 4b. These vectors indicate the position in which the rotor is placed in the interior space of ring core 5. Each neighboring vector has an angular distance from adjacent vectors of 45°. By sending current through the winding segments having the opposite sign, vectors can also be generated in the opposite direction, but they generally have no practical

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significance in applications of the rotary actuator for setting a rotary switch.

The large number of necessary segments makes it difficult to achieve a compact design of the actuator and renders its manufacture time-consuming and expensive.

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From Japanese Laid-Open Patent Application No. 10 178 770, and the related English abstract published in Patent Abstracts of Japan, Volume 1998, No. 11, Sept. 30, 1998, a motor, in particular a stepping motor, is known which has a controllable stop position. This motor has a permanently magnetized rotor and a plurality of stator windings surrounding the

10   rotor in a rim-like fashion, for generating magnetic fields for the purpose of placing the rotor in a plurality of positions. To place the rotor in specific positions, permanent magnets are provided between the stator windings.

Summary Of The [Advantages of the] Invention

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According to the present invention, in a rotary actuator of the type cited above, [means] elements are provided for exerting a corrective torque on the rotor, the [means] elements, in the currentless state of the stator windings, placing the rotor in a target position from a second plurality of positions, a target position being assigned to each position of the first plurality.

20   Therefore, whereas in conventional rotary actuators the stator windings themselves must place the rotor in a target position, in the actuator according to the present invention, this task is taken on by the [means] elements for exerting a corrective torque. Therefore, there no longer exists the requirement that the stator windings must have an arrangement having double symmetry in order to be able to set n different positions in an angular range of 180°.

25   Their arrangement can therefore be simpler, a high degree of symmetry [being necessary] in any case in the [means] elements for exerting the corrective torque. But since the latter is smaller than the torque to be exerted by the stator windings and since the range of the latter can be significantly smaller, it is possible that the [means] elements for exerting the corrective torque can also be significantly smaller and more compact.

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In particular, these [means] elements can be permanent magnets and therefore do not need to be wired.

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Thus according to the present invention, it is possible to arrange the stator windings about the rotor in an unpaired fashion, which cuts in half the number of contacts that are needed for the power supply of the stator windings, and that must be soldered or connected in some other way. The possibility of using a number of stator windings that is smaller than the number of

5   the first positions makes possible a further simplification of the design.

According to one preferred embodiment, the rotary actuator has four first positions and three stator windings.

10   Further features of the rotary actuator according to the present invention and of a rotary switch that is equipped with an actuator of this type can be derived from the description of the exemplary embodiments below.

[Figures] Brief Description Of The Drawings

Figure 1a schematically depicts an exemplary embodiment of a rotary actuator according to the present invention having three stator windings and four first positions.

Figure 1b depicts the vectors that correspond to the magnetic fields generated only by the

20   stator windings and to the target positions of the rotary actuator.

Figure 2 depicts a second exemplary embodiment of a rim-like arrangement of stator windings of a rotary actuator according to the present invention.

25   Figure 3 depicts a network having four inputs and three outputs for supplying the stator windings with current corresponding to the four first positions.

Figure 4 schematically depicts an "R"-type waveguide switch in four different switching positions.

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Figure 5a depicts a conventional arrangement of stator windings; and

Figure 5b depicts the orientation of the magnetic fields generated by the stator windings in Figure 5a.

Detailed Description

5   Figure 1a depicts the [essential] components of a rotary actuator according to the present invention. The actuator includes three stator windings 1, 2, 3, which are arranged in a rim-like fashion, symmetrically about an axis 6 that is perpendicular to the plane of the Figure, at an angular distance in each case of 120°. The stator windings can be selectively connected to an

10   (undepicted) power supply, the polarity of power supply terminals 8 of the stator windings being selected so that windings 1 and 3 generate a magnetic field that is equally oriented with respect to an imaginary circumferential line 9, and stator winding 2 generates a magnetic field having the opposite orientation. Thus as a result of a current being sent through stator windings 1, 2, 3, magnetic fields B_1, B_2, B_3, having the orientations depicted in Figure 1b, are

15   obtained, which are offset by 60° with respect to each other.

A rotor 7, which for the sake of simplicity is depicted in Figure 1a as a bar magnet, can rotate freely about axis 6 under the influence of the magnetic fields generated by stator windings 1, 2, 3; in Figure 1a, it is depicted in the position which corresponds to the case in which only

20   stator winding 1 is supplied with current.

Rotor 7 can adopt other positions corresponding to the orientation of magnetic fields B_2, B_3, if one of windings 2, 3 is supplied with current.

25   Four auxiliary magnets 11, 12, 13, 14 are mounted so as to be radially oriented at different locations outside the area covered by rotor 7 in its rotary motion. A first auxiliary magnet 11 is mounted in a position which shifts the orientation of magnetic field B_1 by 7.5° in the clockwise direction. Auxiliary magnet 11 has a polarity such that it exerts an attractive force on rotor 7 in the position depicted in Figure 1a adopted under the influence of magnetic field

30   B_1. If the power supply to winding 1 is terminated, rotor 7 under the influence of auxiliary magnet 11 rotates to a target position Z_1 (see Figure 1b), in which it is directly facing auxiliary magnet 11.

A further auxiliary magnet 14 is arranged so as to be offset with respect to auxiliary magnet 11 by 45° in the clockwise direction and to have a polarity that is opposite to the latter's. Under the influence of a magnetic field generated by winding 3, rotor 7 adopts a position corresponding to vector B_3 in Figure 1b, if this magnetic field is switched off, rotor 7 under the influence of auxiliary magnet 14 rotates 7.5° to a target position, which corresponds to vector Z_4 in Figure 1b. Vectors Z_1, Z_4 constitute an angle of 135°.

Two further auxiliary magnets 12, 13 are arranged so that they can maintain rotor 7 in target positions Z_2, Z_3. Four target positions Z_1, Z_2, Z_3, Z_4 are offset by 45° with respect to each other.

Auxiliary magnets 11, 12, 13, 14 are dimensioned so that they have the capacity to pull the rotor to themselves from an angular distance of up to roughly +/-20°.

Auxiliary magnets 11, 13, on the one hand, and 12, 14, on the other hand, have different polarities with respect to the radial direction and cooperate with different poles of rotor 7. The influence of each of them can be supported by an (undepicted in Figure 1a) second auxiliary magnet situated diametrically opposite. If the rotary actuator has four target positions, as in the case described here by way of example, there are therefore eight locations at which auxiliary magnets can be arranged. However, it is sufficient if for every target position only one of these two locations is occupied. Preferably, as is depicted in Figure 1a, the one of the two locations is occupied which is left vacant by a stator winding, because this makes the more compact design possible.

As can be seen in Figure 1b, vector B_2 of the magnetic field generated by stator winding 2 lies precisely on the line bisecting the angle between two target positions Z_3 and Z_2. Therefore, it is not possible to set two target positions Z_2 or Z_3, by one of the stator windings being temporarily charged with current and rotor 7 then being left to the influence of the auxiliary magnets, which pull it into the desired target position. For this reason, three stator windings 1, 2, 3 are advantageously provided with current via a network, as depicted in Figure 3. The network has four inputs 20_1 through 20_4 and three outputs 21_1 through 21_3. Inputs 20_1 and 20_4 make it possible for a current to flow via a diode 22_1, or 22_3, to winding 1, or 3, respectively.

If one of these inputs is supplied with current, rotor 7 as a consequence adopts a first position, which corresponds to the orientation of a magnetic field B_1, or B_3. If input 20_2 is supplied with current, one part of the current flows via a diode 22_3 to winding 2 and the rest of the current flows via a diode 22_2 and a resistor 23_1 to winding 1. The magnetic fields generated by windings 1, 2 overlap each other in a field B_{21}, whose vector is depicted in Figure 1b by a dotted line. As a consequence, if input 20_2 is supplied with current, rotor 7 adopts a first position corresponding to field B_{21}, from which, if the power supply is switched off, it can reliably be pulled into target position Z_2 by corresponding auxiliary magnet 12.

If the choice of the resistance value of resistor 23_1 is suitable, the angular distance between B_{21} and Z_2 can be made as small as desired, or the two positions can be brought into agreement.

By analogy to input 20_2, input 20_3 is connected via diode 22_4 to winding 2 and via diode 22_5 and a resistor 23_3 to winding 3, so that a current that is applied to the network at input 20_3 is distributed over windings 2, 3 and results in a superimposed magnetic field B_{21}, as is depicted in Figure 1b by a dotted line.

In this manner, by one of inputs 20_1 through 20_4 of the network in Figure 3 being selectively charged with current, it is possible to place rotor 7 in one of a plurality of first positions and subsequently, under the influence of auxiliary magnets 11 through 14, to cause it to pass to a target position, which can be offset with respect to the first position by a small angle.

Optionally, a resistor 23_3 can be arranged upstream of output 21_2 that is assigned to winding 2, to make the resistance of the arrangement made up of network and windings the same for all inputs 20_1 through 20_4 of the network.

One preferred application of the rotary actuator is the drive of an "R"-type switch 25, as depicted in Figure 4 in different switching positions. This switch 25 has a frame having four input/outputs 26_1 through 26_4 and an adjusting body 27 that rotates in the frame. Adjusting body 27 is coupled to the rotor of an actuator, as is described with regard to Figure 1 and Figure 2, and can therefore be adjusted among four positions, which are depicted in parts a

through d of Figure 4.

Adjusting body 27 contains three channels 28, which in the various switching positions are connected in each case to different input/outputs 26_1... 26_4. In three of the four switching positions, any input/output, for example 26_1, is connected in each case with one of the three other outputs 26_2 through 26_4, and in a fourth switching state it is disconnected.

These "R"-type switches, especially "R"-type waveguide switches, in which the input/outputs and the channels are waveguide for high frequency signals, are used especially in space travel for the redundancy switches in payloads.

It is obvious that the rotary actuator that is described above specifically for the case of three stator windings and four target positions can also be applied for other numbers of stator windings and positions.

In addition, magnetic fields such as magnetic fields B_1, B_2 and B_3 in Figure 1b, which define the first positions of the rotor, do not necessarily have to be generated by one single stator winding. Thus, for example, in the case of Figure 2, if one of the stator windings, for example winding 2, is supplied with a current in accordance with the signs indicated at their terminals 8, it is conceivable, in order to generate field B_2, to simultaneously supply current to stator windings 1 and 3 in series with each other and parallel to winding 2, in accordance with the signs indicated at terminals 8 of windings 1 and 3, so as, in this manner, to strengthen the magnetic field in the interior space of ring core 5, to which rotor 7 is exposed.

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Abstract Of The Disclosure

To simplify the design of a rotary actuator, in particular for an "R"-type waveguide switch, having a permanently magnetized rotor [(7)] and a plurality of stator windings [(1, 2, 3)] surrounding the rotor in a rim-like fashion, for generating magnetic fields which place the rotor in one of a first plurality of positions, it is proposed to furnish the actuator with [means (11, 12, 13, 14)] elements for exerting a corrective torque on the rotor, the [means] elements placing the rotor[(7)], in the currentless state of the stator windings[(1, 2, 3)], in a target position of a second plurality of positions, each position of the first plurality having assigned to it a target position.

[Figure 1a]

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